CLAIMS

What is claimed is:

1. A system for assessing chemical materials manifested as an array of signals, the array being a grid of a plurality of sub-grids of the chemical materials, said system comprising:

a memory storing a digital image of the array; and

a processor for accessing the digital image from said memory and for detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material, segmenting the signal, and calculating a measure of the segmented signal;

said processor segmenting the signal for the chemical material by classifying pixels within the approximate radius of the center-representing pixel as tentative signal pixels and outside the approximate radius from the center-representing pixel as tentative background pixels, determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels, and using pixel intensity relative to the signal major mode and the background major mode to reclassify the tentative signal and background pixels.

2. The system of claim 1 further comprising a scanner for scanning the array and outputting the digital image of the array into said memory.

3. The system of claim 1 further comprising an arrayer, the arrayer depositing the chemical material on a slide to form the array.

4. The system of claim 1, said processor selecting between classifications of contamination, signal, background and undetermined in reclassifying the tentative signal and tentative background pixels.

5. The system of claim 4, said processor finally classifying as contamination pixels the undetermined pixels that are not spatially directly adjacent to a signal pixel and are not spatially adjacent to a signal pixel via other undetermined pixels.

6. The system of claim 4, said processor finally classifying as signal pixels the undetermined pixels that are not spatially directly adjacent to a contamination pixel, that are not spatially adjacent to a contamination pixel via other undetermined pixels, and that are either directly or via other undetermined pixels adjacent to a signal pixel.

7. The system of claim 4, said processor finally classifying the undetermined pixels that are spatially adjacent to both a region of contamination pixels and a region of signal pixels

as signal pixels where the number of pixels in the region of contamination pixels is less than a predetermined fraction of the number of pixels in the region of signal pixels, and

as contamination pixels where the number of pixels in the homogeneous region of contamination pixels is at least the predetermined fraction of the number of pixels in the homogeneous region of signal pixels.

8. The system of claim 7, the predetermined fraction of the number of pixels in the region of signal pixels being about one-third.

9. The system of claim 1, said processor determining a major mode for the tentative signal pixels and a major mode for the tentative background pixels by

generating a signal intensity histogram from the tentative signal pixels and a background intensity histogram from the tentative background pixels,

identifying a peak bin above the median pixel intensity in the signal intensity histogram and a peak bin below the median intensity in the background intensity histogram,

selecting for each histogram a set histogram bins with pixels numbers greater than a predetermined fraction of the number of pixels in the peak bin,

removing from the set of histogram bins for each histogram, histogram bins that are not in a connected group of histogram bins that includes the peak bin,

calculating a slope on each side of the peak bin for the connected group of histogram bins in each histogram,

fitting a slope line on each side of the peak bin for the connected group of histogram bins in each histogram, and

identifying intersection histogram bins that intersect one of the slope lines in each histogram, the major mode for each histogram being the histogram bins between the intersect histogram bins.

10. The system of claim 9, the predetermined fraction of the number of pixels in the peak bin being about seven-tenths.

11. The system of claim 1, the chemical materials being nucleic acid species and the array of signals being a microarray of signals associated with the nucleic acid species.

12. The system of claim 1, said processor determining a measure of performance at detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material, segmenting the signal, and calculating a measure of the segmented signal.

13. The system of claim 12, said processor determining the measure of performance by measuring a spot area for the signal.

14. The system of claim 13, said processor determining another measure of performance by comparing the spot area to an area of the signal.

15. The system of claim 12, said processor determining the measure of performance by determining an ellipticity of the signal.

16. The system of claim 15, said processor determining another measure of performance by determining an orientation of the ellipticity of the signal.

17. The system of claim 12, said processor determining the measure of performance by determining a degree of deviation of the signal from a circle.

18. The system of claim 12, said processor determining the measure of performance by determining an area of contamination in a window around the segmented signal.

19. The system of claim 12, said processor determining the measure of performance by comparing an intensity measure for the signal with an intensity for contamination in a window around the signal.

20. The system of claim 12, said processor determining the measure of performance by measuring a variation in the background major mode.

21. A method of assessing chemical materials manifested as an array of signals, comprising the steps of:

(a) detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material;

(b) segmenting the signal; and

(c) assessing the segmented signal;

the step of segmenting the signal comprising the steps of:

(ba) classifying pixels within the approximate radius of the center-representing pixel as tentative signal pixels and outside the approximate radius from the center-representing pixel as tentative background pixels;

(bb) determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels; and

(bc) using pixel intensity relative to the signal major mode and the background major mode to reclassify the tentative signal and background pixels.

22. The method of claim 21 further comprising a step of generating the digital image of the array.

23. The method of claim 21 further comprising the step of depositing the chemical material on a slide to form the array.

24. The method of claim 21, the tentative signal and background pixels being reclassified by selecting between classifications of contamination, signal, background and undetermined.

25. The method of claim 24, further comprising the step of finally classifying as contamination pixels the undetermined pixels that are not spatially directly adjacent to a signal pixel and are not spatially adjacent to a signal pixel via other undetermined pixels.

26. The method of claim 24, further comprising the step of finally classifying as signal pixels the undetermined pixels that are not spatially directly adjacent to a contamination pixel, that are not spatially adjacent to a contamination pixel via other undetermined pixels, and that are either directly or via other undetermined pixels adjacent to a signal pixel.

27. The method of claim 24, further comprising the step of finally classifying the undetermined pixels that are spatially adjacent to both a region of contamination pixels and a region of signal pixels

as signal pixels where the number of pixels in the region of contamination pixels is less than a predetermined fraction of the number of pixels in the region of signal pixels, and

as contamination pixels where the number of pixels in the homogeneous region of contamination pixels is at least the predetermined fraction of the number of pixels in the homogeneous region of signal pixels.

28. The method of claim 27, the predetermined fraction of the number of pixels in the region of signal pixels being about one-third.

29. The method of claim 21, wherein the step of determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels comprises the steps of:

(bb1) generating a signal intensity histogram from the tentative signal pixels and a background intensity histogram from the tentative background pixels;

(bb2) identifying a peak bin above the median pixel intensity in the signal intensity histogram and a peak bin below the median intensity in the background intensity histogram;

(bb3) selecting for each histogram a set histogram bins with pixels numbers greater than a predetermined fraction of the number of pixels in the peak bin;

(bb4) removing from the set of histogram bins for each histogram, histogram bins that are not in a connected group of histogram bins that includes the peak bin;

(bb5) calculating a slope on each side of the peak bin for the connected group of histogram bins in each histogram;

(bb6) fitting a slope line on each side of the peak bin for the connected group of histogram bins in each histogram; and

(bb7) identifying intersection histogram bins that intersect one of the slope lines in each histogram, the major mode for each histogram being the histogram bins between the intersect histogram bins.

30. The method of claim 29, the predetermined fraction of the number of pixels in the peak bin being about seven-tenths.

31. The method of claim 21, the chemical materials being nucleic acid species and the array of signals being a microarray of signals associated with the nucleic acid species.

32. The method of claim 21, further comprising the step of determining a measure of performance at detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material, segmenting the signal, and calculating a measure of the segmented signal.

33. The method of claim 32, the step of determining the measure of performance being performed by measuring a spot area for the signal.

34. The method of claim 33, the step of determining the measure of performance being performed by comparing the spot area to an area of the signal.

35. The method of claim 32, the step of determining the measure of performance being performed by determining an ellipticity of the signal.

36. The method of claim 35, the step of determining the measure of performance being performed by determining an orientation of the ellipticity of the signal.

37. The method of claim 32, the step of determining the measure of performance being performed by determining a degree of deviation of the signal from a circle.

38. The method of claim 32, the step of determining the measure of performance being performed by determining an area of contamination in a window around the segmented signal.

39. The method of claim 32, the step of determining the measure of performance being performed by comparing an intensity measure for the signal with an intensity for contamination in a window around the signal.

40. The method of claim 32, the step of determining the measure of performance being performed by measuring a variation in the background major mode.

41. A computer readable medium having stored therein one or more sequences of instructions for assessing chemical materials manifested as an array of signals in a digital image, said one or more sequences of instructions causing one or more processors to perform a plurality of acts, said acts comprising:

detecting in the digital image a center-representing pixel and an approximate radius of an signal of a chemical material;

segmenting the signal; and

calculating a measure of the segmented signal;

wherein the signal is segmented by classifying pixels within the approximate radius of the center-representing pixel as tentative signal pixels and outside the approximate radius from the center-representing pixel as tentative background pixels, determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels, and using pixel intensity relative to the signal major mode and the background major mode to reclassify the tentative signal and background pixels.

42. The computer readable medium of claim 41, wherein said acts further comprise selecting between classifications of contamination, signal, background and undetermined in reclassifying the tentative signal and tentative background pixels.

43. The computer readable medium of claim 41, wherein said acts further comprise finally classifying as contamination pixels the undetermined pixels that are not

spatially directly adjacent to a signal pixel and are not spatially adjacent to a signal pixel via other undetermined pixels.

44. The computer readable medium of claim 41, wherein said acts further comprise finally classifying as signal pixels the undetermined pixels that are not spatially directly adjacent to a contamination pixel, that are not spatially adjacent to a contamination pixel via other undetermined pixels, and that are either directly or via other undetermined pixels adjacent to a signal pixel.

45. The computer readable medium of claim 41, wherein said acts further comprise finally classifying the undetermined pixels that are spatially adjacent to both a region of contamination pixels and a region of signal pixels

as signal pixels where the number of pixels in the region of contamination pixels is less than a predetermined fraction of the number of pixels in the region of signal pixels and

as contamination pixels where the number of pixels in the region of contamination pixels is at least the predetermined fraction of the number of pixels in the region of signal pixels.

46. The computer readable medium of claim 45, the predetermined fraction of the number of pixels in the homogeneous region of signal pixels being about one-third.

47. The computer readable medium of claim 41, wherein said act of determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels is performed by

generating a signal intensity histogram from the tentative signal pixels and a background intensity histogram from the tentative background pixels,

identifying a peak bin above the median pixel intensity in the signal intensity histogram and a peak bin below the median intensity in the background intensity histogram, and

selecting for each histogram a connected set of histogram bins that includes the peak bin that corresponds to the major mode for each histogram.

48. The computer readable medium of claim 47, wherein the selection of a connected set histogram bins for each histogram is performed by

selecting for each histogram a set of histogram bins with pixels numbers greater than a predetermined fraction of the number of pixels in the peak bin,

removing from the set of histogram bins for each histogram, histogram bins that are not in a connected group of histogram bins that includes the peak bin,

calculating a slope on each side of the peak bin for the connected group of histogram bins in each histogram,

fitting a slope line on each side of the peak bin for the connected group of histogram bins in each histogram, and

identifying intersection histogram bins that intersect one of the slope lines in each histogram, the major mode for each histogram being the histogram bins between the intersect histogram bins.

49. The computer readable medium of claim 48, the predetermined fraction of the number of pixels in the peak bin being about seven-tenths.

50. The computer readable medium of claim 41, the chemical materials being nucleic acid species and the array of signals being a microarray of signals associated with the nucleic acid species.

51. The computer readable medium of claim 41, wherein said acts further comprise determining a measure of performance at detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material, segmenting the signal, and calculating a measure of the segmented signal.

52. A method of segmenting a signal of a chemical material in a digital image comprising the steps of:

(a) detecting in the digital image a center-representing pixel and an approximate radius of the signal;

(b) classifying pixels within the approximate radius of the center-representing pixel as tentative signal pixels and outside the approximate radius from the center-representing pixel as tentative background pixels;

(c) determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels; and

(d) using pixel intensity relative to the signal major mode and the background major mode to reclassify the tentative signal and background pixels.

53. The method of claim 52, the tentative signal and background pixels being reclassified by selecting between classifications of contamination, signal, background and undetermined.

54. The method of claim 53, further comprising the step of finally classifying as contamination pixels the undetermined pixels that are not spatially directly adjacent to a signal pixel and are not spatially adjacent to a signal pixel via other undetermined pixels.

55. The method of claim 53, further comprising the step of finally classifying as signal pixels the undetermined pixels that are not spatially directly adjacent to a contamination pixel, that are not spatially adjacent to a contamination pixel via other undetermined pixels, and that are either directly or via other undetermined pixels adjacent to a signal pixel.

56. The method of claim 53, further comprising the step of finally classifying the undetermined pixels that are spatially adjacent to both a region of contamination pixels and a region of signal pixels

as signal pixels where the number of pixels in the region of contamination pixels is less than a predetermined fraction of the number of pixels in the region of signal pixels, and

as contamination pixels where the number of pixels in the homogeneous region of contamination pixels is at least the predetermined fraction of the number of pixels in the homogeneous region of signal pixels.

57. The method of claim 56, the predetermined fraction of the number of pixels in the region of signal pixels being about one-third.

58. The method of claim 52, wherein the step of determining a signal major mode for the tentative signal pixels and a background major mode for the tentative background pixels comprises the steps of:

(ca) generating a signal intensity histogram from the tentative signal pixels and a background intensity histogram from the tentative background pixels;

(cb) identifying a peak bin above the median pixel intensity in the signal intensity histogram and a peak bin below the median intensity in the background intensity histogram; and

(cc) selecting for each histogram a connected set of histogram bins that includes the peak bin that corresponds to the major mode for each histogram.

59. The method of claim 58, wherein the step of selecting for each histogram a connected set of histogram bins that includes the peak bin that corresponds to the major mode for each histogram comprises the steps of:

(cc1) selecting for each histogram a set of histogram bins with pixels numbers greater than a predetermined fraction of the number of pixels in the peak bin;

(cc2) removing from the set of histogram bins for each histogram, histogram bins that are not in a connected group of histogram bins that includes the peak bin;

(cc3) calculating a slope on each side of the peak bin for the connected group of histogram bins in each histogram;

(cc4) fitting a slope line on each side of the peak bin for the connected group of histogram bins in each histogram; and

(cc5) identifying intersection histogram bins that intersect one of the slope lines in each histogram, the major mode for each histogram being the histogram bins between the intersect histogram bins.

60. The method of claim 59, the predetermined fraction of the number of pixels in the peak bin being about seven-tenths.

61. The method of claim 52, the chemical materials being nucleic acid species and the array of signals being a microarray of signals associated with the nucleic acid species.

62. The method of claim 52, further comprising the step of determining a measure of performance at detecting in the digital image a center-representing pixel and an approximate radius of a signal of a chemical material, segmenting the signal, and calculating a measure of the segmented signal.